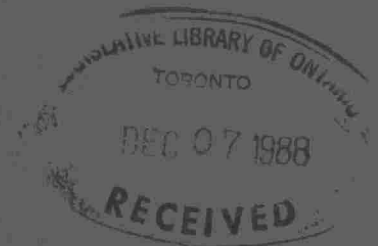


CA20N
EV 610

M18

MATHEMATICS FOR WATER AND SEWAGE OPERATIONS

Training & Certification
1975



RECEIVED

SEP 21 1975

PRINTING SERVICES BRANCH



Ontario

Ministry
of the
Environment

The Honourable
William G. Newman,
Minister

Everett Biggs,
Deputy Minister

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact ServiceOntario Publications at copyright@ontario.ca

MINISTRY OF THE ENVIRONMENT

MATHEMATICS

FOR

WATER AND SEWAGE OPERATIONS

1975

Training and Certification Section
Technical Services Branch
40 St. Clair Avenue West
6th Floor
Toronto, Ontario

© HER MAJESTY THE QUEEN IN
RIGHT OF ONTARIO AS REPRESENTED BY
THE MINISTER OF THE ENVIRONMENT, 1975

1ST PRINTING: SEPTEMBER 1975

Copies may be purchased by writing to:

*Ministry of Government Services
Publications Centre
3rd Basement Level
Macdonald Block, Queen's Park
Toronto, Ontario M7A 1N8*

TABLE OF CONTENTS

<u>SECTION</u>	<u>DESCRIPTION</u>	<u>PAGE NUMBER</u>
A	Objective of the Manual	1
B	Instructions for use of Manual	3
C	Preamble-Approach to Calculations	4
D	Example - Calculations for <u>both</u> Water and Wastewater Treatment Operators	7
E	Working Section for Water Treatment Operators	17
F	Working Section for Wastewater Treatment Operators	24
G	Example - Calculations for Activated Sludge Process	31
H	Working Section for Activated Sludge Operators	43
Appendix 1	milligram/litre to pounds conversion	50
Appendix 2	Geometric formulae Handy Conversion Tables	52

SECTION A

OBJECTIVE OF THIS MANUAL

An operator of a water or wastewater treatment plant should routinely evaluate the efficiency of the plant and of the individual units. To do so, with any degree of accuracy, requires that the operator be familiar with basic mathematical concepts.

The objective of this manual is to help the operator to determine process efficiency through the use of mathematical calculations rather than "trial by error" methods. This manual will not dwell on mathematics in general but rather is intended to act as a guide to the operator in the sense of providing examples of typical "in-plant" calculations.

Water Treatment Plant Operators are required to perform the following in application of their knowledge to "in-plant" processes:

- manipulation of equations and the utilization of formulae
- area, volume and ratio calculations
- dosage calculations for chlorine and other chemicals used in water treatment
- rate of flow calculations.

Wastewater Treatment Plant Operators are required to perform the following in the application of their knowledge to "in-plant" processes:

- manipulation of equations and utilization of formulae
- area, volume and ratio calculations
- dosage calculations for chemicals used in wastewater treatment
- rate of flow calculations
- detention times
- Activated Sludge Calculations including:
 - mixed liquor suspended solids determination (MLSS)
 - volatile suspended solids determination (MLVSS)

- food/microorganism ratio (F/M Ratio)
- sludge wasting
- specific up-take rate (SUR)
- bio-chemical oxygen demand (BOD)
load calculations.

SECTION B

INSTRUCTIONS FOR USE OF MANUAL

This manual is specially designed to be used in conjunction with the Basic Sewage Treatment Operation manual, the Basic Water Treatment Operation manual and the Activated Sludge Workshop course. This manual will accompany the training materials sent out to trainees prior to courses.

It is expected that a certain amount of "pre-study" be undertaken prior to attending a course. The contents should be reviewed by the trainee and the appropriate section, detailed below, is to be completed prior to coming on the course and submitted at the time of course registration. The manual will then be graded, problem areas noted, and then will be used in the mathematics lectures as reference material. Afterwards the manual will be returned to the trainees for their own use.

BASIC SEWAGE TREATMENT OPERATION COURSE -

Trainees attending this course are required to attempt Section F, problems numbered 1 - 13, inclusive.

BASIC WATER TREATMENT OPERATION COURSE -

Trainees attending this course are required to attempt Section E, problems numbered 1 - 16, inclusive.

ACTIVATED SLUDGE WORKSHOP -

Trainees attending this course are required to attempt Section H, problems numbered 1 - 11, inclusive.

SECTION C

PRACTICAL MATH FOR WATER & WASTEWATER TREATMENT PLANT OPERATORS

In most plants routine laboratory tests are performed daily to ensure that the plant is effectively tuned to operate under optimum conditions. The analyses of samples, as determined in the laboratory, will assist the operator in deciding whether any adjustments are necessary to the treatment units to achieve a desirable degree of efficiency of operation. This necessitates that the operator be able to apply the laboratory data made available to him. It is therefore essential that he has a good sound knowledge of basic mathematics to help him more fully understand the significance of test results.

This manual will deal specifically with "in-plant" situations, in an effort to help the operator cope with the necessary calculations, as opposed to attempting to provide a complete understanding of mathematics in general. As a result, the following material contains sample problems indicative of "in-plant" situations as well as a "play-by-play" description of what an operator might consider when solving these. It is intended that the operator will take it upon himself to become familiar with the more fundamental concepts of mathematics. Reference can be made to the publication listed below,* as well as the mathematics sections of our Basic Water and Basic Sewage Manuals and our Activated Sludge Manual.

*Kirkpatrick, J.; "Mathematics for Water & Wastewater Treatment Plant Operators, Book I"
Ann Arbor Science Publications, P.O. Box 1425,
Ann Arbor, Michigan 48106.

THE APPROACH

When one sits down to solve a mathematical problem, how should he approach it? Firstly, don't write anything until you have read the question and determined what is asked. Quite often the questions are "word problems", so rather than focus our attention on the numbers given or the equations included in a problem, we should first ask ourselves some very basic questions about the mathematics problem itself;

- (1) What are you asked to find?
- (2) What concept is involved (e.g. volume, area)?
- (3) Can you draw a diagram or get a picture in your mind of what is going on?
- (4) What are you told about the situation you are asked to solve?
- (5) Are there any formulae you have come across that are applicable to the problem?
- (6) Is there any information not given to you or is it hidden somewhere in the question, perhaps in another form or with different units that need conversion?

Up to this point, you have not used any mathematics. All you have done is examined the situation depicted in the problem. This is why you must understand the "in-plant" processes involved; if you don't, you will find it difficult to do the calculations. Remember that mathematics is a two-way street. With mathematics you can verify that your observations are in line or once given the answer (e.g. from test results), you can decipher what is going on in the plant. There are some basic math concepts that once mastered will make your calculations seem simple. It has already been stressed that mathematics problems are word problems. Once you understand what the situation is, you convert the words into math symbols and eventually equations. The equations quite often look very complex but once you realize that all they do is represent words and ideas concerning plant processes, you will find they aren't difficult at all. As a

result, you should make yourself familiar with the operations and processes involved when dealing with equations. You must be aware of "units"; they tell you in what terms you are talking (e.g. inches, cubic feet per second, etc.) and also you will have to learn how to convert from one unit to another, inches to feet, cubic feet to gallons, etc.

In summary, if you understand completely the processes taking place in your plant and if you make an effort to learn the relatively few basic mathematics concepts involved, math for your in-plant calculations will present no problem at all.

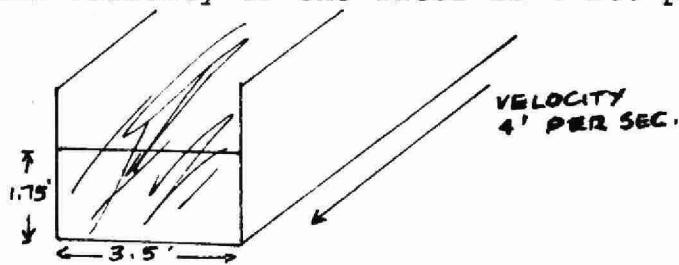
SECTION D

RATE OF FLOW CALCULATIONS

These calculations are important as they provide data that is necessary in determining the cost of treatment and the efficiency of the process control equipment. The accuracy of the flow meters and pumping capacities can be checked and the measurement of flows, contributed by various sources, such as ground water run-off or industrial wastes, can be estimated with some degree of accuracy. Rates of flow must be determined for proper sizing of clarifiers, aeration tanks, grit chambers, etc.

EXAMPLE 1:

A channel 3.5 ft. wide has water flowing to a depth of 1.75 ft. What is the GPM (gallons per minute) FLOW in the channel if the velocity of the water is 4 ft. per second.



$$\begin{aligned}\text{RATE OF FLOW} &= \text{WIDTH} \times \text{DEPTH} \times \text{VELOCITY} \\ &= 3.5\text{ft} \times 1.75\text{ft} \times 4\text{ft/sec.} \\ &= 24.5\text{ft}^3/\text{sec.} \quad \text{or } 24.5 \text{ cubic feet per second}\end{aligned}$$

CHECK UNITS -

$$\text{ft.} \times \text{ft.} \times \frac{\text{ft.}}{\text{sec.}} = \frac{\text{ft.}^3}{\text{sec.}}$$

However, we are asked to find the flow in GPM

Given that 1 ft³ contains 6.24 gals

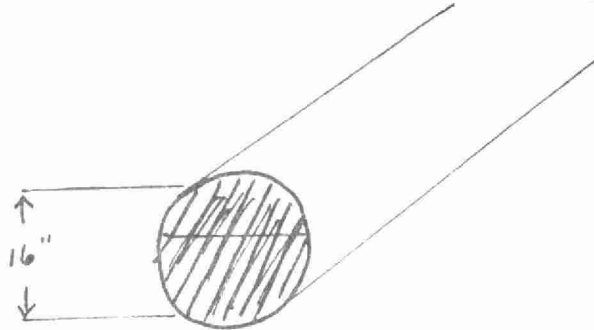
$$\begin{aligned}24.5\text{ft}^3/\text{sec} &= 24.5\text{ft}^3/\text{sec} \times 6.24 \text{ gals/ft}^3 \\ &= 152.88 \text{ gals/sec.}\end{aligned}$$

Therefore if the flow is 152.88 gals/sec

$$\begin{aligned}\text{Then the flow per minute or 60 secs.} &= 152.88 \text{ gals} \times 60 \\ &= 9172.8 \text{ gals/min.}\end{aligned}$$

EXAMPLE 2:

What is the GPD (gallons per day) FLOW in a 16 inch diameter pipe that is flowing 3/4 full if the velocity is 125 ft/min?



$$\begin{aligned}\text{VOLUME OF FLOW} &= \text{CROSS SECTIONAL AREA} \times \text{VELOCITY} \\ &= .75 \pi r^2 \times \text{Velocity} \\ &= (.75)(3.14) \times (.67) \times (.67) \times 125 \text{ ft/min} \\ &= 132.14 \text{ ft}^3/\text{min}\end{aligned}$$

Above we have figured out the CROSS SECTIONAL AREA (using THE AREA OF A CIRCLE FORMULA) of the pipe and multiplied it by .75. This figure represents the Area covered by the flow. Then we simply multiply thru and arrive with an answer in terms of ft^3/min .

We are asked to put the answer in terms of GPD

$$\begin{aligned}\text{In GPD @ } 132.14 \text{ ft}^3/\text{min} &= 132.14 \text{ ft}^3/\text{min} \times 6.24 \frac{\text{gals}}{\text{ft}^3} \times 1440 \text{ min/day} \\ &= 1,187,357 \text{ gals/day}\end{aligned}$$

Check Units -

$$\frac{\text{ft}^3}{\text{min}} \times \frac{\text{gals}}{\text{ft}^3} \times \frac{\text{min}}{\text{day}} = \frac{\text{gals}}{\text{day}}$$

DOSAGE CALCULATIONS

It is very necessary for a plant operator to know how to calculate the dosages of the various chemicals used in water and wastewater treatment. It is important to be accurate when figuring the dosage as too little chemical may be ineffective and too great a dosage a waste of money. As a result, for process control the exact dose of chemical to be added must be determined for the purpose of efficient operation of equipment and for economic considerations.

EXAMPLE 1:

The Chlorine demand of an effluent is 15 mg/l. How many pounds of chlorine will be required to treat a flow of 4.5 MGD (million gallons per day)?

In this question it will be necessary to utilize our knowledge of mg/l to pounds conversions (see page 50)

$$15 \text{ mg/l} = 15\text{ppm} = \frac{15 \text{ lbs Cl}_2}{1,000,000\text{lbs/day}}$$

. . for every 1,000,000 lbs. of water to flow thru we will need to use 15 lbs. chlorine.

If the flow is 4.5 MGD and we know 1 gal weighs 10 lbs. we have 45 million lbs of water flowing thru per day.

$$4.5 \times 10^6 \text{ gals} \times 10 \text{ lbs} = 45 \times 10^6 \text{ lbs}$$

. . for 45 million lbs. flow we will use

$$45 \times 10^6 \text{ lbs/day} \times \frac{15 \text{ lbs Cl}_2}{10^6 \text{ lbs/day}} = 675 \text{ lbs Cl}_2$$

DOSAGE CALCULATIONS

EXAMPLE 2:

A chlorinator is set at 210 lbs/day. If the average daily flow thru the plant is 1.75 MGD, what is the DAILY AVERAGE CHLORINE DOSAGE IN mg/l?

We must convert lbs/day dosage to mg/l dosage

We are told we use 210 lbs chlorine for every 1.75 million gallons water or 17.5 million lbs water (1 gal = 10 lbs).

$$\begin{aligned} \frac{210 \text{ lbs/day Cl}}{(1.75 \text{ MGD}) (10 \text{ lbs/gal}) \text{ Flow}} &= \frac{210 \text{ lbs/day Cl}}{17.5 \text{ M lbs/day flow}} \\ &= \frac{12 \text{ lbs Cl}}{1 \text{ mill lbs/day}} = \underline{\underline{12 \text{ mg/l}}} \end{aligned}$$

Above we divided pounds of chlorine used per day by the flow (in pounds). And found we used 12 lbs chlorine for every million pounds flow or 12 mg/l.

HYPOCHLORITE CALCULATION:

Definition - A hypochlorite is a compound of chlorine and another chemical usually applied in the form of a solution for disinfection purposes.

EXAMPLE 1:

The secondary effluent at a treatment plant required a chlorine dosage of 98 lbs/day for disinfection purposes. If we are using a solution of hypochlorite containing 60% available chlorine, how many pounds/day hypochlorite will be required?

SOLUTION:

We are told in the problem that 60% of the hypochlorite is available chlorine which is the portion of the solution capable of disinfecting

$$\begin{aligned} \cdot \cdot \quad (60\%) \text{ (hypochlorite solution)} &= \text{available chlorine} \\ (60\%) \text{ (lbs/day hypochlorite)} &= 98 \text{ lbs/day Cl.} \\ (.6) (X \text{ lbs/day}) &= 98 \end{aligned}$$

Solving for X we have -

$$X \text{ lbs/day hypochlorite} = \frac{98}{.6}$$

$$X = 163.3 \text{ lbs/day hypochlorite}$$

HYPOCHLORITE CALCULATIONS

EXAMPLE 2:

A hypochlorite solution contains 5% available chlorine. If 8 lbs of available chlorine are needed to disinfect a main, how much 5% solution would be required?

We are told 8lbs. of chlorine will do the job of disinfection.

By a 5% solution we mean that 5% by weight of the solution is to be made up of chlorine. So 100 lbs of 5% hypochlorite solution will contain 5 lbs chlorine.

or

100 lbs 5% solution contains 5 lbs chlorine

20 lbs. 5% solution contains 1 lb. chlorine

. . 8 lbs chlorine diluted to 5% will cause the
solution to weigh $8 \times 20 \text{ lbs} = 160 \text{ lbs}$ hypochlorite
solution

PERCENT

EXAMPLE 1:

A solution weighs 80 lbs and is 85 % water and the remainder is lime. What is the weight of lime?

The total solution weighs 80 lbs or represents 100%; if the water represents 85% then the lime represents

$$\begin{array}{rcl} 100\% & - & 85\% = 15\% \text{ lime} \\ \text{Total} & & \text{Water} \\ \text{Weight} & & \end{array}$$

$$\begin{aligned} \therefore \text{Weight of lime} &= 15\% \times 80 \text{ lbs} \\ &= .15 \times 80 \text{ lbs} = 12 \text{ lbs.} \end{aligned}$$

PERCENT

EXAMPLE 2:

A liquid mixture of 200 lb. in weight contains 176 lb. of water and the rest is Alum.

(a) What is the Percent Water?

(b) What is the Percent Alum?

SOLUTION

(a) In the above question we are told the total weight of the mixture is 200 lbs. or 100%.

Weight of Alum is 176 lbs.

$$\frac{\text{Weight of Alum}}{\text{Total Weight}} = \frac{176}{200}$$

And to find the percentage simply multiply by 100%

$$\frac{176}{200} \times 100\% = 88\% \text{ Alum}$$

(b) Obviously if 88% of the mixture is water then -

$$\begin{array}{rcl} 100\% & - & 88\% = 12\% \text{ water} \\ \text{(Total Weight)} & & \text{(Alum)} \end{array}$$

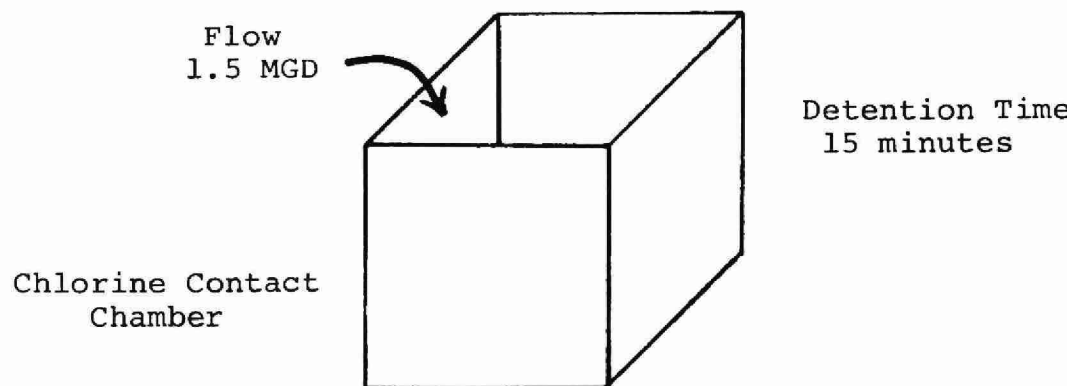
DETENTION TIME

As an operator, you are aware that during various stages in the treatment process the flow must be contained in certain tanks or sections of the plant for specified periods of time. The reason being is that it takes time for the various treatment operations to occur. In the sewage treatment process there are varying detention times recommended for the treatment of certain kinds of raw sewage in the aeration section. In the water treatment process, it is necessary to retain the flow in the coagulation - flocculation section for a period long enough for the floc to form but not too long so as to begin to break up the floc. In the design phase sizing of clarifiers and aeration tank is determined according to both the detention time required and rate of flow.

EXAMPLE:

A water Treatment Plant has an average daily flow of 1.5 MGD. If the average detention time in the chlorine contact chamber is 15 min., what should the volume of the chamber be, in Cubic Feet?

DIAGRAM



SOLUTION:

If 1.5 MG flows through in 1 day or 24 hrs. then in 1 hr. what is the flow?

$$\frac{1,500,000 \text{ gals}}{24 \text{ hrs.}} = 62,500 \text{ gals/hr.}$$

What is the flow in 15 min or $\frac{1}{4}$ hr.

$$\frac{62,500 \text{ gals/hr}}{.25 \text{ hr.}} = 15,625 \text{ gals}/\frac{1}{4} \text{ hr.}$$

If this is the expected flow in 15 min., then common sense tells us that the chlorine contact chamber must be big enough to contain at least this flow, 15,625 gals.

However, we are asked to give our answer in cubic feet(ft^3)

Remember in 1 cu.ft. of water there are 6.24 gals.

$$\therefore \text{ in } 15,625 \text{ gals there are } \frac{15,625 \text{ gals}}{6.24 \text{ gals/ft}^3} = 2504 \text{ ft}^3$$

SECTION E

BASIC MATH - WATER TREATMENT OPERATION

Part A - Volumes & Areas

1. Calculate the surface area of a rectangular settling tank 60 feet long and 20 feet wide.
2. Calculate the surface area of a circular sand filter that is 21 feet in radius.
3. What is the volume of a chlorine contact chamber that is 25 feet long, 8 feet wide, and 6 feet deep?

4. What is the volume of a cylindrical storage tank that is 14 feet in diameter and 15 feet high?

5. What is the volume contained by 252 feet of 4" pipe?

•

9. The prechlorination chamber at a water treatment plant has a volume of 50,000 gallons. If the flow rate out of the tank is 0.2 MGD, what is the average detention time?
10. How many pounds of chlorine are required each day to treat 4.0 MGD with chlorine at 5.0 ppm?
11. A gas chlorinator treats 0.6 MGD with 4.5 lb. of chlorine each day. Calculate the dosage rate. The residual is measured at 0.3 ppm. What is the chlorine demand?

PART C - Dosage

12. In the chart below you are required to determine the pounds of chemical that will be required to dose at the rate indicated along the top of the chart in relationship to the amount of water flowing in which is indicated along the side.

dosage amt. rate of water	1.0 ppm	2.0 ppm	4.0 ppm	10 ppm	0.5 ppm
1,000,000 lb.					
4,000,000 lb.					
20,000,000 lb.					
500,000 lb.					
200,000 gal.					

13. In the chart below you are required to determine the dosage in either ppm or mg/l that coincide with the flow indicated on the vertical scale and the pounds of alum indicated on the horizontal scale.

amt. of amt. alum of water	1.0 lb.	2.0 lb.	5.0 lb.	20 lb.	0.4 lb.
1,000,000 lb.					
5,000,000 lb.					
10,000,000 lb.					
200,000 lb.					

Part D - Percent

14. A liquid mixture of 200 lb. weight in total contains 176 lb. of water and the rest is alum.
a) Calculate the percent that is water.
b) Calculate in percent the fraction that is alum.
15. A solution of water and powdered carbon is to be 85% water. If the total volume of solution required is 800 gallons, how much powdered carbon is needed?
16. A hypochlorite solution contains 12% available chlorine. If 8 lb. of available chlorine are needed to disinfect a main, how many lb. of 12% solution are required? How many gallons?

BASIC WATER TREATMENT MATH (EXTRA PRACTICE CALCULATIONS)

Problem Set 2

1. Calculate the volume contained by 100 feet of pipe that is 14" in diameter.
2. A rectangular storage tank for an alum solution that is 20 feet long, 15 feet wide, and 10 feet deep after filling takes 30 days to empty. What is the average rate at which the alum solution is being used up? (Express the answer in GPD)
3. A solution is composed of three substances - water, powdered carbon and alum and the total weight is 2,000 lbs. Calculate the weight of each substance if it is known that 70% is water and 25% is carbon.
4. A water treatment plant has a flow of 0.6 MGD. If the average detention time in the chlorine contact chamber is to be 12 minutes, what should the volume of the chamber be?
5. A 0.0005% concentration of copper sulphate is suggested for controlling algae in a certain reservoir. The volume of the reservoir is 40 million gallons. How many pounds of copper sulphate are required?
6. A well produces 0.4 MGD and is chlorinated by using 56 lb. of chlorine each week. Calculate the dosage rate.
7. An operator is attempting to chlorinate a well water supply using a hypochlorinator. The well pump rate is 100 GPM, the hypochlorite solution is 20% available chlorine and the required dose is 2.5 ppm. How many gallons of hypochlorite solution should be used each day?

SECTION F

BASIC MATH - SEWAGE OPERATION

Part A - Volumes and Areas

1. What is the surface area of a rectangular clarifier 20 feet wide and 60 feet long?
2. What is the surface area of a circular clarifier 21 feet in radius?

3. What is the volume of a chlorine contact chamber 25 feet long, 8 feet wide, and 6 feet deep?

4. What is the volume of a cylindrical storage tank that is 14 feet in diameter and 15 feet high?

Part B - Rate

5. If a pump pumps 300 gallons in 20 minutes, what is the pumping rate in i) GPM, ii) GPH?

6. An 80 GPM pump operates for 5 minutes. How much water is pumped?

7. A 2,700 gallon alum storage tank supplies alum for phosphorus removal treatment at a rate of 4.5 gallons per hour. How often will the tank need refilling?

8. Water flows through a rectangular channel 3 feet wide and 2 feet deep at a speed of 8 ft./sec. What is the flow rate in -
- a) ft./sec.?
 - b) gallons per minute?

9. The aeration section of a 0.2 MGD plant has a volume of 50,000 gallons. What is the average detention time?

PART C - Dosage

10. In the chart below you are required to determine the pounds of chemical that will be required to dose at the rate indicated along the top of the chart in relationship to the amount of water flowing in which is indicated along the side.

dosage amt. rate of water	1.0 ppm	2.0 ppm	4.0 ppm	10 ppm	0.5 ppm
1,000,000 lb.					
4,000,000 lb.					
20,000,000 lb.					
500,000 lb.					
200,000 gal.					

11. In the chart below you are required to determine the dosage in either ppm or mg/l that coincide with the flow indicated on the vertical scale and the pounds of alum indicated on the horizontal scale.

amt. of amt. alum of water	1.0 lb.	2.0 lb.	5.0 lb.	20 lb.	0.4 lb.
1,000,000 lb.					
5,000,000 lb.					
10,000,000 lb.					
200,000 lb.					

12. How many pounds of chlorine are required each day to dose the effluent of a 4.0 MGD plant at 5.0 p.p.m.?
13. A gas chlorinator is set to dose the effluent of a 0.6 MGD with 24 lb. of chlorine each day. If the chlorine demand is 3.0 p.p.m., calculate the chlorine residual.

BASIC SEWAGE TREATMENT OPERATION (EXTRA PRACTICE CALCULATIONS)

Problem Set 2

1. An aerator tank is 8 feet deep, 20 feet wide and 50 feet long. Calculate its volume in -
 - a) cubic feet
 - b) gallons
2. A 120,000 gallon tank has a detention time of 5 hour. Calculate the flow in -
 - a) gallons per hour
 - b) gallons per day
3. The venturi meter at a plant records a fairly constant flow of 400 G.P.M. while at the same time the operator observes that the flow in the channel (2 feet wide and 1.5 feet deep) is about 1 foot per second. Is the meter recording accurately?
4. If the chlorine dosage rate at a 0.3 MGD plant is 6.0 p.p.m., how many pounds of chlorine are consumed each day?
5. Raw sewage entering the primary clarifier has a suspended solids content of 250 mg/l. The concentration is reduced to 150 mg/l in the primary effluent and 15 mg/l in the final effluent. Calculate the efficiency (in percent) of the -
 - a) primary section and
 - b) the whole plant

SECTION G

ACTIVATED SLUDGE CALCULATIONS

EXAMPLE:

MIXED LIQUOR SUSPENDED SOLIDS DETERMINATION (MLSS)

GIVEN:

Sample volume of mixed liquor used = 50 ml
Dried disc weight (Tare Weight) = 0.2157 gm
Dried weight of disc + solids = 0.4376 gm

Determine the MLSS in mg/l

$$MLSS = \frac{(B-A) \times \overset{(1)}{1000} \times \overset{(2)}{1000}^*}{V}$$

Where

B = Dried weight of disc and solids in grams
A = Dried disc weight (weight in grams)
V = Volume of sample used in ml

$$\begin{aligned} \therefore MLSS &= \frac{0.4376 \text{ gm} - 0.2157 \text{ gm} \times 1000 \times 1000 \text{ mg/l}}{50 \text{ ml}} \\ &= \frac{(.2219 \text{ gm}) \times 1000 \times 1000 \text{ mg/l}}{50} \\ &= 4438 \text{ mg/l} \end{aligned}$$

* MLSS is usually reported in mg/l. In the formula the
#1 - 1000 is there to convert the weight to mg's while
#2 - 1000 ensures that the figures are relative to 1000 ml
or 1 litre. This is to report the MLSS in mg/l.

F/M RATIO

F/M RATIO (FOOD/MICROORGANISM RATIO) - is the relationship between the weight of food (measured by the BOD of the aerator influent) and the weight of microorganisms in the aerator (as measured by the MLVSS).

EXAMPLE 1:

A conventional activated sludge treatment plant receives a daily flow of 4.5 MGD with a primary effluent BOD of 165 mg/l. If 15,000 lbs of MLVSS* are maintained in the aerator, what is the F/M ratio?

SOLUTION:

FIRST, BEFORE determining the F/M loading ratio, we must calculate the pounds of BOD entering the aerator daily. Therefore, we must convert mg/l BOD to pounds of BOD daily.

$$(165 \text{ mg/l}) (4.5 \text{ MGD}) (10 \text{ lbs/gals}) = 7425 \text{ lbs BOD/day}$$

$$\begin{aligned} \therefore F/M &= \frac{\text{lbs BOD daily}}{\text{lbs MLVSS in aerator}} = \frac{7425 \text{ lbs BOD}}{15,000 \text{ lbs MLVSS}} \\ &= .495 \end{aligned}$$

(* for MLVSS calculation see Topic 8, Activated Sludge Manual)

SLUDGE WASTING:

In order to attain an equilibrium in the food to microorganisms ratio, it will be necessary to "waste" some activated sludge. Continuous wasting that is proportional to the degree of organic loading in the incoming flow or batch wasting, at times of low hydraulic loads, are two ways in which this process may be achieved. The amount of sludge to be wasted can be determined if the suspended solids in the aeration tank and sludge return are measured. The excess solids are determined by comparing the desired solids in the system with the existing solids.

EXAMPLE:

Given the MLSS = 5300 mg/l, and the aeration tank capacity is 275,000 gallons. Calculate (i) how many gallons of sludge must be diverted to waste in order to reduce the MLSS to 4200 mg/l, and (ii) (a) if wasted continuously over a 24-hour period, what would be the pumping rate per hour? and (b) if batch wasted over a 6-hour period, what would be the pumping rate per hour?

SOLUTION:

Formula -

$$X = \frac{(M_o - M_1) V}{R}$$

Where M_o = MLSS (mg/l)

M_1 = Required MLSS (mg/l)

V = Volume aeration tank (gal)

R = suspended solids in sludge return (mg/l)

X = gallons to waste

(i) The solution of the above problem requires only substitution of given values into the formula.

$$\begin{aligned} X &= \frac{(5300 \text{ mg/l} - 4200 \text{ mg/l}) (275,000 \text{ gals})}{9800 \text{ mg/l}} \\ &= \frac{1100 \text{ mg/l} \times 275,000 \text{ gals}}{9800 \text{ mg/l}} \\ &= 30,867 \text{ gals.} \end{aligned}$$

(ii) (a)

$$\begin{aligned} \text{Amount of sludge to be wasted} &= 30,867 \text{ gals} \\ \text{Time period of wasting} &= 24 \text{ hrs} \\ \therefore \text{Pumping Rate} &= \frac{30,867 \text{ gals}}{24 \text{ hrs}} = 1286.13 \text{ gals/hr.} \end{aligned}$$

(ii) (b)

$$\begin{aligned} \text{Amount of sludge to be wasted} &= 30,867 \text{ gals} \\ \text{Time period of wasting} &= 6 \text{ hrs} \\ \therefore \text{Pumping Rate} &= \frac{30,867 \text{ gals}}{6 \text{ hrs}} = 5144.5 \text{ gals/hr.} \end{aligned}$$

CLARIFIER UPFLOW RATE

The amount of wastewater flowing into a clarifier relative to the surface area of the clarifier is known to affect the settleable solids and BOD removal efficiency during sedimentation.

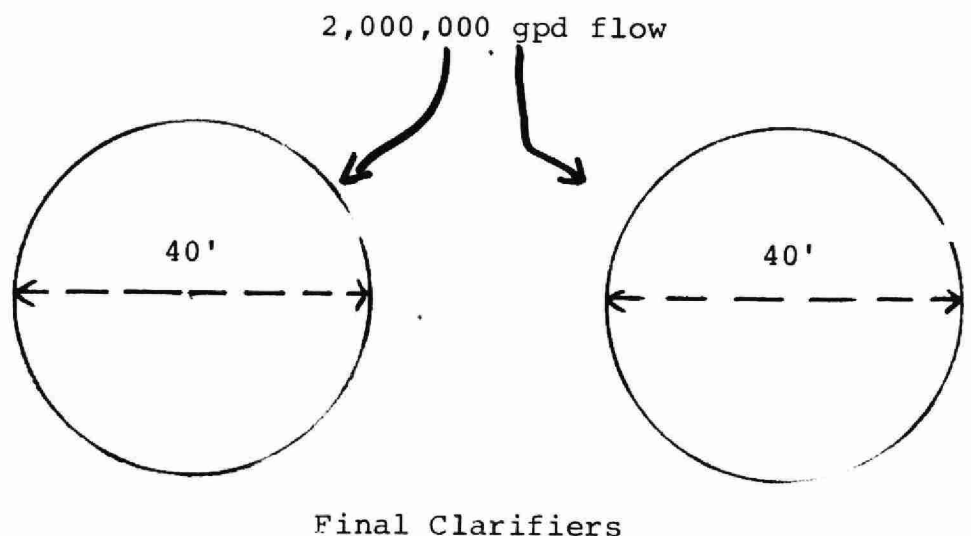
A means of determining this "surface loading rate" is to compare the number of gallons of wastewater entering the clarifier to the surface area of the clarifier. The units of measurement are therefore gallons of wastewater daily per square foot of clarifier surface area or -

$$\frac{\text{average daily flow (gals)}}{\text{surface area of final clarifier (sq.ft.)}}$$

EXAMPLE:

The flow to a treatment plant is 2 MGD. If there are two final clarifiers, each with a diameter of 40 feet, calculate the clarifier upflow rate.

SOLUTION:



Referring to the above formula, note the information required. Given the daily flow as 2 MGD, it is necessary to calculate the surface area of the final clarifiers.

. . using area of a circle formula

$$A = \pi r^2 \text{ or } \frac{\pi d^2}{4}$$

given a diameter of 40', the surface area of one final clarifier is

$$\frac{3.14 (40)^2}{4} = 1256 \text{ sq.ft.}$$

However, there are two final clarifiers; therefore total clarifier surface area is

$$2 \times 1256 \text{ sq.ft.} = 2512 \text{ sq.ft.}$$

$$\text{. . Upflow Rate} = \frac{2,000,000 \text{ gals daily}}{2512 \text{ sq.ft.}}$$

$$= 796.18 \text{ gals/sq.ft./day.}$$

SLUDGE VOLUME INDEX (S.V.I.)

The Sludge Volume Index (S.V.I.) is defined as the volume, in millilitres, that is occupied by 1 gram of activated sludge after a 30 minute settling test. Normal activated sludge generally has an SVI value in the range of 70-125.

EXAMPLE:

If the mixed liquor settled to 285 ml or 28.5% after the 30 minute settling test and the concentration of the mixed liquor suspended solids (MLSS) is 3250 mg/l, what is the SVI.

SOLUTION:

$$\begin{aligned} \text{SVI}^* &= \frac{30 \text{ min. settling test result (ml)} \times 1000}{\text{MLSS (mg/l)}} \\ &= \frac{285 \text{ ml} \times 1000}{3250 \text{ mg/l}} \\ &= \underline{\underline{87.7}} \end{aligned}$$

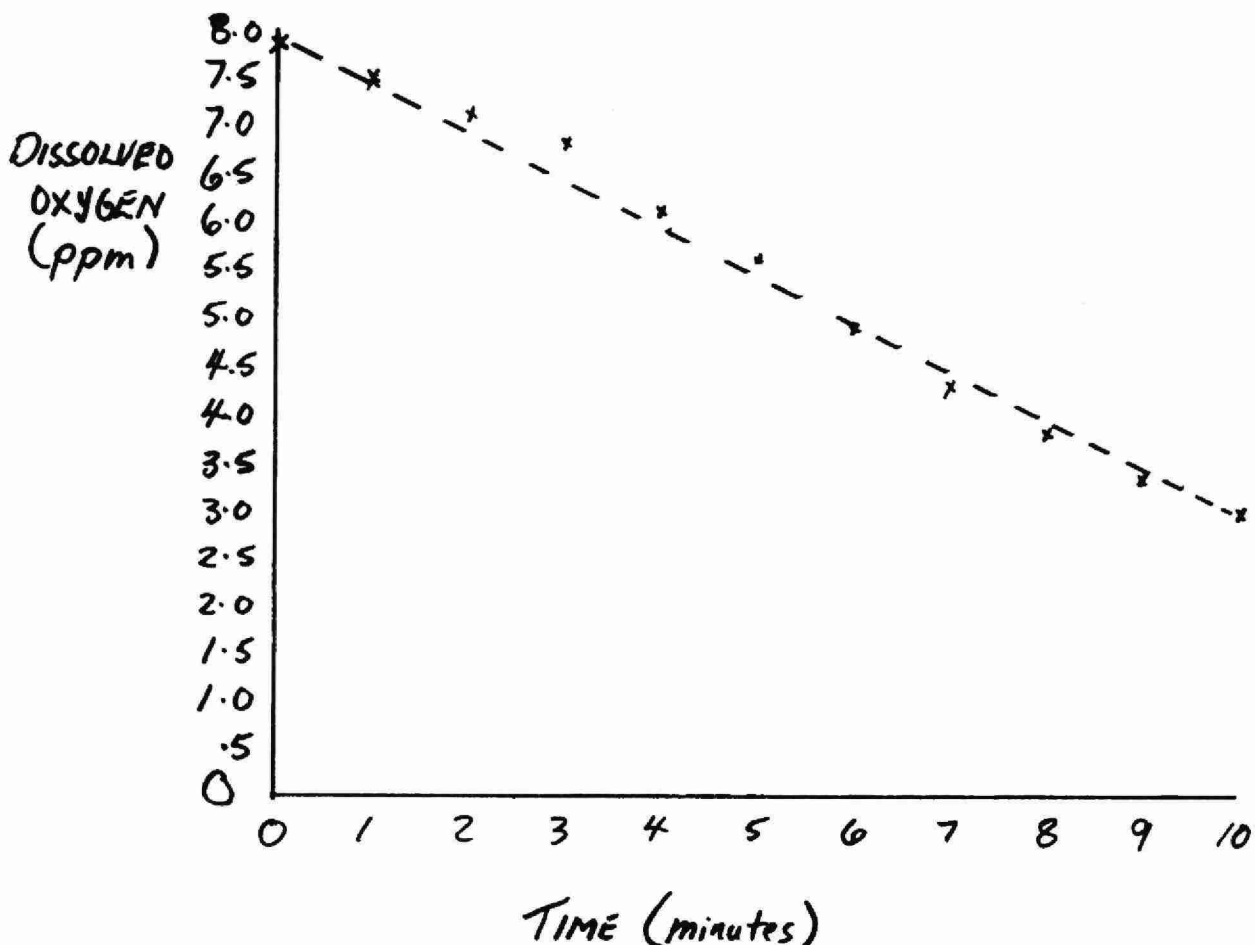
*Alternate formula for SVI = $\frac{30 \text{ minute settling test result}}{\text{MLSS in grams}}$

RESPIRATION RATES

The respiration rate, in the context of an activated sludge plant, is the rate at which the micro-organisms within the aeration tanks use up oxygen. Another phrase for this process is Oxygen Uptake Rate. Respiration rates or uptake rates vary according to the solids concentration in the aeration tank. As a result, the uptake rate is frequently expressed as the "Specific Uptake Rate" (SUR) and this means the amount of oxygen utilized in one hour by one gram of mixed liquor volatile suspended solids.

EXAMPLE:

From the information provided on the following graph, calculate the oxygen uptake rate and given a volatile suspended solids value of 2400 ppm, calculate the specific uptake rate.



It can be seen from the graph that the DO value at time zero is 7.8 mg/l and the value at time 10 minutes is 3.0 mg/l. By subtracting the lower DO value from the higher and dividing by the time interval, the slope can be determined as follows:

$$\frac{7.8 \text{ mg/l} - 3.0 \text{ mg/l}}{10 \text{ min.}} = .48 \text{ mg O}_2/\text{l/min.}$$

The uptake rate is expressed in the units mg O₂/l/hr.

$$\begin{aligned} \therefore \text{Uptake rate} &= .48 \text{ mg O}_2/\text{l/min.} \times 60 \text{ min/hr} \\ &= \underline{28.8 \text{ mg O}_2/\text{l/hr.}} \end{aligned}$$

$$\text{Specific Uptake Rate (SUR)} = \frac{\text{Uptake rate} \times 1000}{\text{MLVSS (ppm)}}$$

$$= \frac{28.8 \text{ mg O}_2/\text{l/hr} \times 1000}{2400 \text{ ppm}}$$

$$= 12 \text{ mg O}_2/\text{l/hr/gm MLVSS}$$

ORGANIC LOADING (BOD Volume Load)

Organic loading of a trickling filter refers to the daily pounds of BOD entering the trickling filter volume. This concept is expressed as

$$\text{Organic Loading} = \frac{\text{lbs BOD/day}}{\text{cu.ft.volume}}$$

EXAMPLE 1:

A standard rate trickling filter has a diameter of 108 feet and a media depth of 6 feet. The flow into the filter is 500 gallons per minute with a BOD concentration of 85 mg/l. What is the BOD loading per 1000 cu. ft.?

SOLUTION:

First we must determine the gallons per day flow

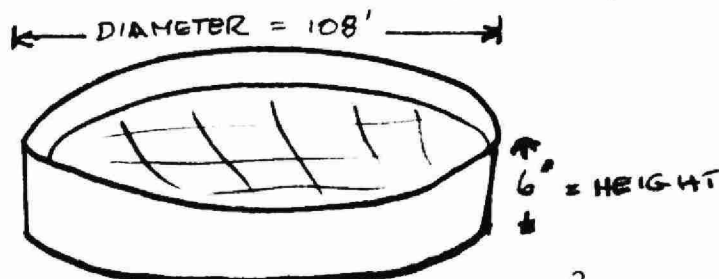
Pumping rate per minute = 500 gallons

$$\begin{aligned} \therefore \text{pumping rate per day} &= (500 \text{ gals/min}) (1440 \text{ min/day}) \\ &= 720,000 \text{ gals/day} \\ &= .72 \text{ mgd} \end{aligned}$$

Next we calculate lbs BOD/day

$$\begin{aligned} 85 \text{ mg/l} &= \frac{85 \text{ lbs BOD}}{1 \text{ million lbs flow}} (.72 \text{ mgd}) (10 \text{ lbs/gal}) \\ &= 612 \text{ lbs BOD/day} \end{aligned}$$

Because organic loading is a weight to volume relationship we must determine the volume of the trickling filter.



$$\text{Volume of a cylinder} = \frac{\pi D^2}{4} \times H$$

$$\text{Volume} = \frac{(3.14)(108)(108)}{4} \times 6' = 54937 \text{ ft}^3$$

Now we can utilize the relationship

$$\begin{aligned}\text{Organic Loading} &= \frac{\text{lbs BOD/day}}{\text{cu. ft. volume}} \\ &= \frac{612 \text{ lbs BOD/day}}{54,937 \text{ ft}^3} \\ &= \frac{0.0111 \text{ lbs BOD/day}}{1 \text{ ft}^3}\end{aligned}$$

However, we want our answer in terms of lbs BOD/1000 ft³

$$\frac{0.0111 \text{ lbs BOD} \times 1000}{1 \text{ ft}^3 \times 1000} = \frac{11.1 \text{ lbs BOD/day}}{1000 \text{ ft}^3}$$

ORGANIC LOADING

EXAMPLE 2:

An aeration tank has the following dimensions:
20' x 50' x 15'. The flow to the aeration tank is 1.3 MGD
with a BOD concentration of 70 mg/l. Calculate the BOD
loading per 1000 cu.ft.

SOLUTION:

Calculate lbs BOD/day

$$\begin{aligned} 70 \text{ mg/l} &= \frac{70 \text{ lbs BOD}}{1 \times 10^6 \text{ lbs flow}} \times 1.3 \times 10^6 \text{ gals} \times 10 \text{ lbs/gal} \\ &= 910 \text{ lbs BOD/day} \end{aligned}$$

Next, determine volume of aeration tank.

$$\begin{aligned} V &= l \times w \times h \\ &= 50' \times 20' \times 15' \\ &= 15,000 \text{ cu.ft.} \end{aligned}$$

$$\text{Since Organic Loading} = \frac{\text{lbs BOD/day}}{\text{aeration tank volume (cu.ft.)}}$$

$$\therefore \frac{910 \text{ lbs BOD/day}}{15,000 \text{ cu.ft.}} = \frac{0.0607 \text{ lbs BOD/day}}{1 \text{ cu.ft.}}$$

Again, as in the previous example, the answer is to be
in terms of lbs BOD/1000 cu.ft.

$$\therefore \frac{0.0607 \text{ lbs BOD} \times 1000}{1 \text{ cu.ft.} \times 1000} = \frac{60.7 \text{ lbs. BOD}}{1000 \text{ cu.ft.}}$$

SECTION H

ACTIVATED SLUDGE PROBLEMS

- (1) A 50 ml aliquot of mixed liquor is filtered for a suspended solids analysis. The tare weight of the paper is 0.174 gram. After filtering and drying, the paper weighed 0.324 gram. What is the MLSS concentration?

- (2) Given a raw sewage flow of 1 MGD and a BOD in the raw sewage of 150 mg/l, calculate the lb. of BOD per day entering the activated sludge section assuming a 20% reduction in BOD across the primary clarifiers.

- (3) Given that a plant has a daily flow of 1.0 MGD and an average primary effluent BOD of 150 mg/l, mixed liquor volatile suspended solids (MLVSS) of 1500 mg/l and an aeration tank volume of 200,000 gallons, calculate the F/M ratio.
- (4) If the uptake rate is 20 mg O_2 /l/hr and the MLVSS is 4,000 mg/l, what is the specific uptake rate?

- (5) A 100,000-gallon aeration tank contains 4,000 mg/l MLSS. The return sludge concentration is 12,000 mg/l. How many gallons of sludge should be wasted in order to reduce the MLSS to 3,000 mg/l?

- (6) Calculate the MLSS and SVI using the following information:

- (a) Weight of paper = 0.4004
- (b) Weight of paper
 - + solids = 0.5186
 - Sample volume = 50 mls
 - 1/2 hour SVI = 21%

- (7) A 250-ml sample of final effluent is filtered for a suspended solids analysis. The tare weight of the paper is 0.1560 gram. After filtering and drying, the paper weight is 0.1572 gram. Express the suspended solids concentration in mg/l
- (8) An aeration tank has a capacity of 500,000 gallons. If the MLSS is 3,000 mg/l, what is the weight of the solids expressed in lbs?
- (9) The MLSS concentration in a 200,000-gallon aeration tank is 4,000 mg/l. This activated sludge contains 75% volatile suspended solids. Express the MLVSS in lbs.

- (10) A flow of 1.7 mgd is entering a conventional activated sludge treatment plant. The BOD concentration in the raw sewage is 265 mg/l. If the primary treatment stage of the process removes 23% of the BOD and the F/M ratio in the aerator is 50 lbs BOD/100 lbs MLVSS, how many pounds MLVSS should be maintained in the aerator.

- (11) The following pertinent data are noted for a typical activated sludge plant.

2-primary settling tanks each 52' x 16' x 10' water dimension (W.D.) with four full width weirs at the effluent end.

4 aeration tanks each 72' x 18' x 10' W.D.

2-blowers each at 850 ft³/min

2-final settling tanks each 56' x 16' x 10' W.D.

1 chlorine contact tank 37' x 12' x 7' W.D.

1 digester 52' diameter (Ø) x 24' W.D.

The results of flow studies and samples indicate:

FLOW:	1,000,000 gallons daily
Raw BOD:	200 ppm
Primary BOD:	130 ppm
Final BOD:	15 ppm
Raw Suspended Solids:	250 ppm
Primary Suspended Solids:	100 ppm
Final Suspended Solids:	15 ppm
Raw Sludge:	3% Solids
Raw Sludge:	70% Volatile
Digested Sludge:	10% Solids

(The British system of units is used in all measurements)

Determine the following:

- (1) Detention time in primary tanks
- (2) Weir overflow rate in l. gal/ft/day in primary tank
- (3) Air supply in ft³/gal of sewage
- (4) Detention time in aeration tank with 25% return of activated sludge
- (5) Percent removal of BOD achieved in the plant.

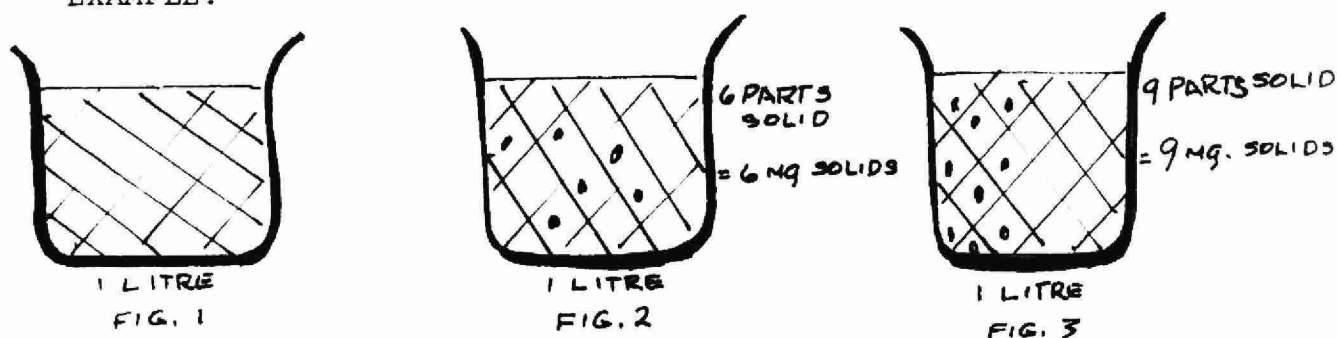
- (6) Percent removal of Suspended Solids achieved in the plant
- (7) Detention time in chlorine contact tank
- (8) Total pounds of BOD removed
- (9) Total pounds of Suspended Solids removed in the plant
- (10) Gallons of sludge pumped to digester
- (11) Pounds of volatile solids to digester
- (12) Cubic feet of digester space per pound of volatile solids added

Round off answers to significant figures.

MILLIGRAM/LITRE to POUNDS COVERSION

Concentrations such as BOD, suspended solids or chemical dosages are normally reported in terms of milligrams per litre (mg/l). Milligrams per litre is therefore a measure of concentration.

EXAMPLE:



$$1 \text{ litre} = 1,000,000 \text{ parts} = 1,000,000 \text{ mg}$$

In fig. 1, the volume contained is 1 litre and has been divided into 1 million parts, each part representing 1 milligram (mg). The concentration of solids in the litre could be expressed as:

- (1) The number of mg. solids per 1,000,000 mg.
- (2) The number of mg. solids per one litre

$$\text{or mathematically } \frac{\text{mg. solids}}{\text{litre}} = \frac{\text{mg}}{1}$$

As a result the concentration of solids, shown in fig. 2 may be expressed as 6 mg/l and likewise the concentration in Fig. 3 as 9 mg/l.

An additional method of reporting solids concentration is in terms of parts per million (ppm) or parts solids per million parts of the litre. Observe that ppm is a weight to weight relationship. Whereas, mg/l is a weight to volume relationship. Therefore, when converting from mg/l to ppm remember to convert the volume units to units of weight. The

reason that these two terms, mg/l and ppm, are commonly used interchangeably is that 1 ml of water weighs approximately 1 gram. As a result for most purposes mg/l concentration and ppm concentration can be equated.

$$\text{mg/l} = \text{ppm}$$

You may generalize this concept even further -

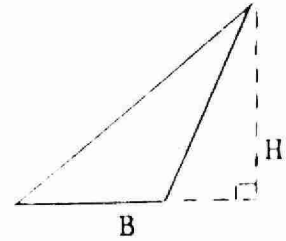
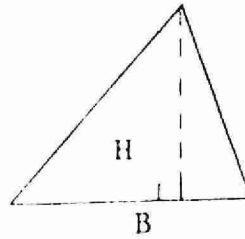
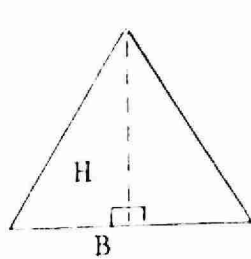
$$\begin{aligned}\text{part per million parts} &= \text{grams per million grams} \\ &= \text{pounds per million pounds} \\ &= \text{tons per million tons}\end{aligned}$$

When converting mg/l to pounds you should ask yourself, how many millions of pounds daily flow do you actually have. If, for example knowing that 1 gal weighs 10 lbs, if you knew you had a flow of 1 million gals per day, you could convert this to lbs by multiplying by 10 to realize that you have 10 million pounds per day flow.

A water works operator is often called upon to figure out areas and volumes. The types of figures which he is most likely to encounter are shown below:

Areas

(1) Triangle

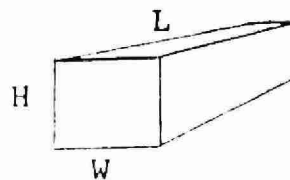


The area of a triangle:

$$A = \frac{1}{2} \text{ base } \times \text{ height}$$

$$= \frac{1}{2} B \times H$$

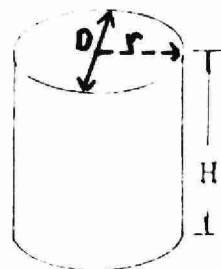
(2) Rectangular Solid



The volume of a rectangular solid:

$$V = L \times W \times H$$

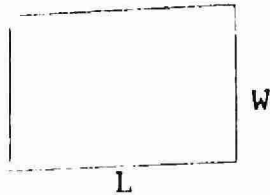
(3) Cylinder



The volume of a cylinder:

$$V = \frac{\pi D^2}{4} \times H$$

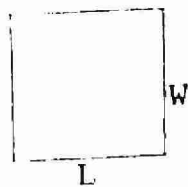
(2) Rectangle



The area of a rectangle:

$$A = L \times W$$

(3) Square



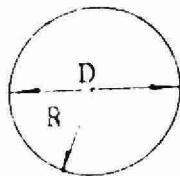
The area of a square:

$$A = L \times W$$

but $L = W$

$$\text{Therefore } A = L^2$$

(4) Circle



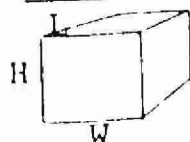
The area of a circle:

$$A = \pi R^2 \quad \text{or} \quad \frac{\pi D^2}{4}$$

D = diameter
R = radius = $1/2D$
C = circumference
 $\pi = 3.14$

Volumes

(1) Cube



The volume of a cube:

$$V = L \times W \times H = L^3$$

all three sides equal
 $L = W = H$

HANDY CONVERSION CHART

LINEAR

1 inch (in)	= 2.540 centimeters (cm)
1 foot (ft)	= 12 inches (in)
1 yard (yd)	= 3 feet (ft)
1 mile (mi)	= 5,280 feet
1 meter (m)	= 39.37 in. = 3.281 ft = 1.094 yd.
1 meter	= 100 centimeters

AREA

1 square foot (ft ²)	= 144 square inches (in ²)
1 square yard (yd ²)	= 9 square feet
1 acre	= 43,560 square feet
1 square mile	= 640 acres

VOLUME

1 cubic foot (ft ³)	= 1728 cubic inches (in ³)
1 cubic yard (yd ³)	= 27 cubic feet (ft ³)
1 cubic foot	= 6.24 gallons (Imp.gals)
1 gallon	= 4 quarts (qts.)
1 litre	= 1000 millilitres (ml)

WEIGHT

1 pound (lb)	= 16 ounces = 7000 grains = 453 6 grams
1 ounce (oz.)	= 28.35 grams (gms.)
1 kilogram (kg)	= 1000 grams
1 gram	= 1000 milligrams (mg)
1 cu.ft. water	= 62.4 pounds (lbs.)
1 gallon water	= 10 pounds water
1 litre water	= 1 kilogram water
1 millilitre water	= 1 gram water

HANDY FORMULAE CHART

$$\text{Average Daily Flow} = \frac{\text{total sum of all daily flows}}{\text{number of days}}$$

$$\begin{aligned} \text{Flow in rectangular channel in Cubic Feet/sec (ft}^3/\text{sec)} \\ = (\text{width ft})(\text{depth ft})(\text{velocity ft/sec}) \end{aligned}$$

$$\begin{aligned} \text{Flow in a circular channel (or pipe) in Cubic Feet/sec} \\ (\text{ft}^3/\text{sec}) \\ = (\text{cross sectional wetted area of circle})(\text{velocity ft}^3/\text{sec}) \end{aligned}$$

$$\text{Weir Overflow Rate (gpm/linear ft)} = \frac{\text{gpm flow}}{\text{total feet of weir}}$$

$$\text{Pumping Rate (gpm)} = \text{Influent Rate (gpm)} - \text{gpm due to level change after pump is started}$$

$$\text{Hydraulic Loading (gals/sq ft/day)} = \frac{\text{gpd flow}}{\text{sq.ft.surface area}}$$

$$\text{F/M Ratio} = \frac{\text{lbs BOD/day to aeration tanks}}{\text{lbs MLVSS in aeration tanks}}$$

$$\text{MLSS} = \frac{(\text{B} - \text{A}) \times 1000 \times 1000}{\text{V}}$$

B= dried weight of disc + solids (gm)

A= dried disc weight (gm)

V= volume of sample (ml)

$$\text{Organic Loading} = \frac{\text{lbs BOD/day}}{\text{cu.ft. volume}}$$

Sludge Volume Index (SVI)

$$= \frac{30 \text{ minute settling test result (ml) in 1000 ml cylinder} \times 100}{\text{MLSS (mg/l)}}$$

$$\% \text{ Suspended Solids removed} = \frac{\text{mg/l suspended solids removed} \times 100}{\text{total mg/l suspended solids}}$$

$$\% \text{ Settled Sludge} = \frac{\text{ml settled sludge} \times 100}{\text{ml total sample}}$$

$$\text{Chlorine Dosage} = \text{Chlorine Demand} + \text{Chlorine Residual}$$

Fahrenheit Degrees to Celsius Degrees:

$$C^{\circ} = \frac{5}{9} (F^{\circ} - 32^{\circ})$$

Celsius Degrees to Fahrenheit Degrees:

$$F^{\circ} = \frac{9}{5} (C^{\circ} + 32^{\circ})$$

LEGISLATIVE LIBRARY OF ONTARIO



9693600020167